held together by the forceps, and *slightly* warmed, just sufficient to soften the gutta percha ; the forceps may now be laid aside, or used simply to press the cover home, warming the slide gently, also the cover ; the perfect contact of the softened " tissue" with the cover and slide is easily recognized, and with a little care this can be effected very quickly, and nothing further is necessary. A finishing ring of colored cement makes a very neat mount, but it is not necessary.

ON MULTIPLE SPECTRA.

"Nunc age, quo motu genitalia materiai
Corpora res varias gignant, genitasque resolvant
Et qua vi facere id cogantur."
Lucretius ii., 61–2.

" Prima moventur enim per se primordia rerum :
Inde ea, quæ parvo sunt corpora conciliatu,
Et quasi proxima sunt ad vireis principiorum,
Ictibus illorum cæcis impulsa cientur
Ipsaque, quæ porro paulo maiora, lacessunt."
Lucretius, ii., 132–6.

"It is conceivable that the various kinds of matters, now recognized in different elementary substances, may possess one and he same ultimate or atomic molecule existing in different conditions of movement.

"The essential unity of matter is an hypothesis in harmony with the equal action of gravity upon all bodies."—*Graham's Researches*, p. 299.

In a recent paper * I showed that a study of the minute anatomy of spectra, both terrestrial and celestial, forces upon us the conclusion that both in the electric arc and in the hottest region of the sun the so-called chemical elements behave after the manner of compound bodies.

I then dealt more especially with the question of the basic lines in the various spectra, and it is clear that if at any one temperature, there be some lines only truly basic in the spectrum of any element, we at once divide the lines visible at that temperature into two groups, those which are basic and those which are not. This would give a compound origin to the lines, and this is the real point.

It is now years ago since the view was first held that the elementary bodies had double spectra, that is, that each, of at all events several, under changed conditions of temperature or electric tension, gave us now a fluted spectrum and now one composed of lines.

I glimpsed the idea some time afterward that the line spectrum was in its turn in all probability a complex whole, in other words that it was the summation of the spectra of various molecular groupings.

Recent work has to my mind not only shown that this is true, but that in the case of many bodies the complexity, and therefore the number, of the molecular groupings which give rise to that compound whole called a line spectrum, is considerable.

It is therefore important from my point of view to reconsider the evidence on which the assertion that the fluted bands and the line spectrum (taken as a whole) of a substance really belong to that substance, because if we find that this must be accepted and that it can easily be explained on the view that the two kinds of spectra are produced by different molecular groupings, the fact of other molecular groupings, giving rise to a complex line spectrum can be more readily accepted, contrary though it be to modern "chemical philosophy," as taught at all events in the text-books.

Plücker and Hittorf were, I believe, the first to point out that the same chemical substance, when in a state of gas or vapor, gave out different spectra under different conditions. On this point they wrote fifteen years ago :

" The first fact which we discovered in operating with our tubes . . was the following one :

" *There is a certain number of elementary substances which, when differently heated, furnish two kinds of spectra of quite a different character, not having any line or any band in common.*

" The fact is important, as well with regard to theoretical conceptions as to practical applications—the more so as the passage from one kind of spectrum to the other is by no means a continuous one, but takes place abruply. By regulating the temperature you may repeat the two spectra in any succession *ad libitum*." (Plücker and Hittorf on the Spectra of Ignited Gases and Vapors : *Phil. Trans.* Royal Society, 1865, part i. p. 6.)

Angström, whose name must ever be mentioned with the highest respect by any worker in spectrum analysis, was distinctly opposed to this view, and in the text which accompanies his *Spectre Normal* we find the following statement :

" Dans un Mémoire sur les spectres ' doubles' des corps élémentaires que nous publierons prochaînement, M. Thalén et moi, dans les Actes de la Société des Sciences d'Upsal, nous traiterons d'une manière suffisamment complète les questions importantes qu'on peut se proposer sur cet intéressant sujet. Pour le présent, je me borne à dire que res résultats auxquels nous sommes arrivés, ne confirment aucunement l'opinion émise par Plücker, qu'un corps élémentaire pourrait donner, suivant sa température plus ou moins élevée, des spectres tout-à-fait différents. C'est le contraire qui est exact. En effet en augmentant successivement la température, on trouve que les raies varient en intensité d'une manière trèscompliquée, et que, par suite, de nouvelles raies peuvent même se présenter, si la température s'élève suffisamment. Mais, independamment de toutes ces mutations, le spectre d'un certain corps conservera toujours son caractère individuel." *

Angström did not object merely on theoretical grounds. He saw, or thought he saw, room to ascribe all these fluted spectra to impurities.

He was strengthened in this view by observing how, in the case of the spectra of known compounds, there were always flutings in one part of the spectrum or another ; a rapid induction naturally, therefore, ascribed all flutings to compounds. The continuity of the gaseous and liquid states of matter, let alone the continuity of Nature's processes generally, never entered into the question. For Angström, as for the modern chemist, there was no such thing as evolution, no possibility of a close physical relationship between elements, so called, driven to incandescence from the solid state, and binary compounds of those elements.

In a memoir, however, which appeared after Angström's death, and which, though under a different title, was in all probability the one referred to, this opinion was to a large extent recalled, and in favor of Plücker's view, in the following words :—

". . . Nous ne nions certainement pas qu'un corps simple ne puisse dans certains cas donner différents spectres. Citons, par exemple, le spectre d'absorption d'iode que ne ressemble en aucune facon au système des raies brillantes du même corps, obtenues au moyen de l'électricité ; et remarquons de plus qu'en général tout corps simple, presentant la propriété d'allotropie, doit donner à l'état d'incandescence des spectres différents, pourvu que la dîte propriété de la substance subsiste non seulement à l'état gazeux du corps, mais encore à la température même de l'incandescence. . . .

"Le soufre solid possède, somme on sait, plusieurs états allotropiques, et, d'après certaines observations, ce corps, même à son état gazeux, prendrait des formes différentes. Par conséquent, en supposant que cela soit vrai, le soufre gazeux doit donner plusieurs spectres d'absorptio, tandis que la possibilité d'un seul on de plusieurs spectres brillants dépendra de la circonstance suivante, savoir si les états allotropiques plus complexes de cette substance supporteront la température de l'incandescence, avant de se décomposer.

* "On the Necessity for a New Departure in Spectrum Analysis" (NATURE, vol. xxi. p. 8.)

* Angström sur " Le Spectre normal du Soleil," page 39.

"Il est bien évident que les cas dont nous venons de parler, ne forment pas une exception à la loi générale énoncée ci-dessus, savoir que chaque corps simple ne peut donner qu'un seul spectre. En effet, si l'on suppose que l'état allotropique est dû à la constitution moléculaire du corps, soit que les molécules se combinent les unes avec les autres, soit qu'elles s'arrangent entre elles d'une certaine manière, cet état allotropique possèdera au point de vue spectroscopique, toutes les propriétés significatives d'un corps composé, et par conséquent il doit être décomposé de la même façon que celui-ci par les effets de la décharge disruptive de l'électricité."[1]

I say that in this paper Angström recalled his own in favor of Plücker's view, because (as it has been remarked by Dr. Schuster[2]) the word "element" is used in a special sense—because in reality allotropic states are classed as compounds, that particular allotropic state which is to be regarded as truly elemental not being stated, nor any reason given why one should be thus singled out.

In the letter to which I have just referred Dr. Schuster gives an instance in which in order to show that elementary bodies did not really possess two spectra, a double spectrum was assigned to an acknowledged compound; the fluted spectra of hydrogen and carbon which differ from each other as widely as fluted spectra can, being both ascribed to acetylene.

Salet in his admirable work on the Spectra of the Metalloids,[3] was driven to the conclusion that many of these bodies must be held to possess two spectra. His conclusions are thus expressed :—

"Nous avons comparé le spectre d'absorption du brome et de l'iode à leur spectre électrique, et cette comparaison nous semble mettre hors de doute la possibilité des spectres doubles. . . .

"Nous avons obtenu, par voie électrique, un spectre primaire de l'iode correspondant à son spectre d'absorption. Le soufre, le sélénium et le tellure nous ont offert des spectres de combustion très-analogues aux spectres primaire obtenus par voie électrique, mais différant essentiellement des spectres des lignes. . . .

"Nous avons produit le spectre primaire de l'azote avec différents corps qui n'ont absolument de commun que l'azote; nous pensons donc avoir démontré qu'il appartient bien réellement à ce métalloïde." (*Annales de Chemie et de Physique*, 4 série, tome xxviii. pp 70, 71).

In 1868 Wullner[4] gave his attention to this subject, and strongly supported Plücker's view of the existence of double spectra, indicating at the same time that the difference of temperature must be regarded as the sole cause of the phenomenon, adding, however, "a decomposition with further elements is not to be thought of." In the case of hydrogen he showed that the banded spectrum ascribed to acetylene really depended upon a change in the emissive power brought about by an alteration of temperature. Touching oxygen, he showed that three distinct spectra may be obtained, while in nitrogen two are observed.

I may say that in my early laboratory experiments I was at first led to think that, in the case of metallic vapors, Angström's first expressed opinion was correct, and I said so. But after more experience and knowledge had been acquired, I was compelled by the stern logic of facts to abandon it, and I showed, first, that more "orders" of spectra—to use Plücker's term—were necessary, and then that the line spectrum itself was in all probability compound; that is, that it was in some cases built up by the vibration of dissimilar molecules, some of which might even give us a fluted spectrum, if we could study them alone.

Although, however, in the views I have expressed on former occasions I have had the advantage of the support of the opinion of Plücker and Angström, and later of Dr. Schuster,[2] not to mention others, I am aware that though there is a general consensus among spectroscopic workers that double spectra cannot be ascribed to impurities, it is not absolute.

I propose therefore in this place to refer to a special case in which this question has been recently brought prominently forward.

[1] Ångström and Thalén's "Recherches sur les Spectres des Métalloides," p, 5.

[2] NATURE, vol. xv. p. 447.

[3] *Ann. de Chimie et de Physique*, 1873, vol. xxviii. p. 1.

[4] *Phil. Mag.*, sec. 4, vol. xxxvii. p. 405.

I have already stated that Angström, who was the first to map the line-spectrum of carbon, ascribed the flutings ordinarily seen in the carbon compounds to acetylene.

Now Attfield, in 1862, as a result of a most carefully conducted and admirably-planned set of experiments, came to the conclusion that the flutings were really due to carbon: in short, that carbon, like hydrogen, iodine, sulphur, nitrogen, and other bodies, had a fluted spectrum as well as one consisting wholly of lines.

The work of Attfield will be gathered from the following extract from his paper (*Phil. Trans.*, vol. clii. part 1, p. 221 *et seq.*) :—

"On recently reading Swan's paper by the light that Professors Bunsen and Kirchoff have thrown on the subject, I came to the conclusion that these bands must be due to the incandescent carbon vapor; that, if so, they must be absent from flames in which carbon is absent, and present in flames in which carbon is present; that they must be observable equally in the flames of the oxide, sulphide, and nitride as in that of the hydride of carbon; and, finally, that they must be present whether the incandescence be produced by the chemical force, as in burning jets of the gases in the open air, or by the electric force, as when hermetically-sealed tubes of the gases are exposed to the discharge of a powerful induction-coil. . . .

"To establish the absolute identity of the hydro- and nitro-carbon spectra, excluding of course the lines due to nitrogen, they were simultaneously brought into the field of the spectroscope: one occupying the upper, and the other the lower half of the field.

"This was readily effected after fixing the small prism, usually supplied with spectroscopes, over half of the narrow slit at the further end of the object-tube of the instrument. The light from the oxyhydrocarbon flame was now directed up the axis of the tube by reflection from the little prism, while that from the oxynitrocarbon flame passed directly through the uncovered half of the slit. A glance through the eye-tube was sufficient to show that the characteristic lines of the hydrocarbon spectrum were perfectly continued in the nitrocarbon spectrum. A similar arrangement of apparatus, in which the hydrocarbon light was replaced by that of pure nitrogen, showed that the remaining lines of the nitrocarbon spectrum were identical with those of the nitrogen spectrum. In this last experiment the source of the pure nitrogen light was the electric discharge through the rarefied gas.

"The above experiment certainly seemed to go far towards proving the spectrum in question to be that of the element carbon. Nevertheless, the ignition of the gases having been effected in air, it was conceivable that hydrogen, nitrogen, or oxygen had influenced the phenomena. To eliminate this possible source of error, the experiments were repeated out of contact with air. A thin glass tube 1 inch in diameter and 3 inches long, with platinum wires fused into its sides, and its ends prolonged by glass quills, having a capillary bore, was filled with pure dry cyanogen and the greater portion of this gas then removed by a good air-pump. Another tube was similarly prepared with olefiant gas. The platinum wires in these tubes were then so connected with each other that the electric discharge from a powerful induction-coil could pass through both at the same time. On now observing the spectra of these two lights in the simultaneous manner previously described, the characteristic lines of the hydrocarbon spectrum were found to be rigidly continued in that of the nitrocarbon. Moreover, by the same method of simultaneous observation, the spectrum of each of these electric flames, as they

[1] Dr. Schuster's recently published investigations are as follows :—

Mr. Lockyer's investigations have shown that most bodies give us a continuous spectrum, as a gas, before they condense, and many at a considerable temperature above the boiling point. *Mr. Lockyer has rightly drawn the conclusion from these facts, that the atomic aggregation of the molecules is the cause of the different orders of spectra.*

That the discontinuous spectra of different orders (line and band spectra) are due to different molecular combinations, I consider to be pretty well established, and analogy has led me (and Mr. Lockyer before me) to explain the continuous spectra by the same cause; for the change of the continuous spectrum to the line or band-spectrum takes place in exactly the same way as the change of spectra of different orders into each other. Analogy is not a strong guide, yet some weight may be given to it in a case like the one under discussion, where experiment hitherto has failed to give a decided answer. (Dr. A. Schuster on the Spectra of Metalloids, *Phil. Trans.* Royal Society, 1879. Part i. page 38 and 89, note).

may be termed, was compared with the corresponding chemical flames, that is, with the oxhydrocarbon and oxynitrocarbon jets of gas burning in air. The characteristic lines were present in every case. Lastly, by similar interobservation a few other lines in the electric spectrum of the hydrocarbon were proved to be due to the presence of hydrogen, and several others in the electric spectrum of the nitrocarbon to be caused by the presence of nitrogen. . . .

"The spectrum under investigation having then been obtained in one case when only carbon and hydrogen were present, and in another when all elements but carbon and nitrogen were absent, furnishes to my mind, sufficient evidence that the spectrum is that of carbon."

"But an interesting confirmation of the conclusion just stated is found in the fact that the same spectrum is obtained when no other elements but carbon and oxygen are present, and also when carbon and sulphur are the only elements under examination. And first with regard to carbon and oxygen. Carbonic oxide burned in air gives a flame possessing a continuous spectrum. A mixture of carbonic oxide and oxygen burned from a platinum-tipped safety-jet also gives a more or less continuous spectrum, but the light of the spectrum has a tendency to group itself in ill-defined ridges. Carbonic oxide, however, ignited by the electric discharge in a semi-vacuous tube, gives a bright sharp spectrum. This spectrum was proved, by the simultaneous method of observation, to be that of carbon plus the spectrum of oxygen. With regard to carbon and sulphur almost the same remarks may be made. Bisulphide of carbon vapor burns in air with a bluish flame. Its spectrum is continuous. Mixed with oxygen and burned at the safety-jet, its flame still gives a continuous spectrum, though more distinctly furrowed than in the case of carbonic oxide; but when ignited by the electric current its spectrum is well defined, and is that of carbon plus the sulphur. That is to say, it is the spectrum of carbon plus the spectrum that is obtained from vapor of sulphur when ignited by the electric discharge in an otherwise vacuous tube."

"Having thus demonstrated that dissimilar compounds containing carbon emit, when sufficiently ignited, similar rays of light, I come to the conclusion that those rays are characteristic of ignited carbon vapor, and that the phenomena they give rise to on being refracted by a prism is the spectrum of carbon."

This question was next taken up by Morren. He wrote[1] (in 1865) fifteen years ago:

"A la réception de cet intéressant et substantiel Mémoire, j'avoue que je ne regardai pas d'abord comme fondée l'assertion de M. Attfield. . . .

"Je me suis donc mis au travail avec la pensée préconçue de combattre l'assertion émise par le savant anglais; mais pas du tout, il résulte au contraire des expériences auxquelles je me suis livré que M. Attfield a raison, et que c'est bien la vapeur du carbone qui donne le spectre indiqué plus haut. . . .

"Si on fait brûler le cyanogène au moyen du chalumeau à deux courants, en faisant arriver au centre de la flamme du cyanogène un courant d'oxygène très-pur (cette condition est indispensable), on voit se produire un des plus beaux effets de combustion possible, et cette expérience est certainement une des plus magnifiques qu' on puisse réaliser sur la combustion des gaz. Il se produit, au milieu de la flamme *rosé-violâtre* du cyanogène, une boule d'un blanc vert éboulissant qui rappelle la lumière électrique produite par le courant de la pile entre deux charbons de cornue. Si le spectroscope est dirigé sur cette brillante lumière, on aperçoit, avec une splendeur merveilleuse, le même spectre de la partie bleue des flammes hydrocarburées. Ainsi donc c'est du charbon seul, mais à l'état de vapeur, qui forme cette boule brillante qui plus loin, par son union avec l'oxygène, va passer à l'état d'acid carbonique. Du reste ce spectre n'est pas seul; avec lui on voit, mais très-effacé, le spectre spécial du cyanogène, et celui-ci tend de plus en plus à disparaître à mesure que l'oxygène arrive avec plus d'abondance et brûle de mieux en mieux le cyanogène. Quant au spectre de l'azote, on ne l'aperçoit pas dans cette vive lumière. Le magnifique éclat de ce beau spectre, le plus beau qu'il m'ait été donné de voir, permet de bien comprendre l'aspect creusé et ombré avec une teinte croissante qu'on remarque dans les parties qui n'ont pas de raies brillantes, et même entre ces raies."

Four years later Dr. Watts devoted himself to this subject, and in 1869 his work was thus summarized by himself:[1]

"This spectrum [that consisting of the flutings in question] may be obtained from the flame of any hydrocarbon, though in many cases, owing to the faintness of the spectrum, only some of the groups can be recognized. In the flame of an ordinary Bunsen burner δ and ε are easily seen, γ and f are much fainter, and the red group can not be detected.

"This spectrum is proved to be that of carbon, inasmuch as it can be obtained alike from compounds of carbon with *hydrogen*, with *nitrogen*, with *oxygen*, with *sulphur*, and with *chlorine*. I have obtained it, namely, from each of the following compounds: olefiant gas, cyanogen, carbonic oxide, naphthalin, carbonic disulphide, carbonic tetrachloride, amylic alcohol, and marsh-gas."

That these conclusions, successively arrived at by Attfield, Morren, and Watts, are sound, I shall show in my next notice.—("*Nature.*") J. NORMAN LOCKYER.

(*To be continued.*)

VALUE OF BISULPHIDE OF CARBON IN MICROSCOPICAL DEFINITION.

AT the last meeting of the R. M. S. (the last of the session), on the 9th instant, a paper was read by Mr. J. W. Stephenson, treasurer of the society, discussing the relative visibility of objects mounted in media of different refractive indices. Some time ago, Mr. Stevenson called attention to the fact that if diatoms were mounted in bisulphide of carbon their fine structure was rendered far more visible than when mounted in Canada balsam. Since the explanations given by Professor E. Abbe on the introduction of his new expression for apertures (*i.e.*, "numerical aperture"), by which the relative resolving power of different objectives is seen by the reading of the numerical apertures, Mr. Stephenson has come to the conclusion (in which he stated Professor Abbe agreed with him) that the *visibility* of objects is dependent on the *difference* of the refractive indices of the *object* observed and the *medium* in which it is placed. This he illustrates as follows:

Taking the refractive index of air as 1.0, and diatomaceous silex as 1.43, the visibility may be expressed by the *difference* 43.

Mr. Stephenson gave the following table:—

Refractive indices (taken approximately).		Visibility of silex (Refr. index = 1.43).
Water	= 1.33	10
Canada balsam	= 1.54	11
Bisulphide of carbon	= 1.68	25
Sol. of sulphur in bisulph.	= 1.75	32
,, phosphorus ,,	= 2.10	67

These data relating to visibility must, doubtless, be regarded in direct connection with the numerical aperture of the objectives of the illumination, as pointed out by Mr. Stephenson. He gave practical demonstrations of the views explained in his paper by exhibiting several slides mounted in the different media. I mention one slide of *Pleurosigma Elongatum*, mounted in sol of phosphorus in bisulphide of carbon, as presenting to the eye the strongest image that has come under my notice. According to Mr. Stephenson's theory, the visibility under these conditions would be about six times as great as that of the same object mounted in balsam. Is it possible to induce our professional object-mounters to take up the subject? Surely there are many amateurs of fine definition who would like to see the conditions of visibility pushed to the highest point, and who would amply repay the modicum of exertion needed to produce them.

[1] *Annales de Chimie et de Physique*, 4 série, tome iv. p. 309, 312.

[1] *Phil. Mag.*, October, 1869.